4. Ecological Toxicity Data

The Agency has adequate data to assess the toxicity of *parent* Terbufos to nontarget organisms. The Agency has no information on toxicity of Terbufos *metabolites*.

a. Toxicity to Terrestrial Animals

i. Birds, Acute and Subacute

In order to establish the toxicity of Terbufos to birds, the minimum data required on the technical material are:

• An avian single-dose LD_{50} test with either one species of waterfowl, preferably the mallard, or one species of upland gamebird, preferably bobwhite (section 71-1); and

• Two avian dietary LC_{50} tests, one with a species of waterfowl, preferably the mallard, and one with a species of upland gamebird, preferably the bobwhite (section 71-2).

The acceptable avian acute oral toxicity studies are listed below:

Avian Acute Oral Toxicity Findings

Species	% AI	LD_{50} (mg/kg)	Conclusions
Bobwhite quail	89.6	29 (95% CI 22-57)	highly toxic
	tech	15 (12-19)	highly toxic

These results show that Terbufos is highly toxic to birds. The guideline requirement for the avian acute oral LD_{50} study is fulfilled. (# FEOTER02)

The acceptable avian subacute dietary studies are listed below:

Avian Subacute Dietary Toxicity Findings

Species	% AI	LC_{50} (ppm)	Conclusions
Mallard Duck	86	520 (95% CI 400-676)	moderately toxic
	86	160 (131-195)	highly toxic
Bobwhite Quail	87.8	157 (125-201)	highly toxic
	86	140 (107-183)	highly toxic

On a subacute dietary basis, Terbufos is moderately to highly toxic to birds. The guideline requirement is fulfilled. (MRID 00035120, 00087717, 00160387)

ii. Birds, Chronic

Avian reproduction studies are required because Terbufos is expected to persist in soil with a half life greater than four days. In order to establish the chronic toxicity of Terbufos to birds, the data required on the technical material are:

Two avian reproduction studies (71-4), one with a species of waterfowl, preferably the mallard, and one with a species of upland gamebird, preferably the bobwhite quail.

Avian reproduction studies on technical Terbufos are listed below.

Avian Reproduction Findings

Species	% A.I.	Conclusions
Mallard Duck	tech	No significant impairment at 2-20ppm dietary levels, but approaching significance at 20ppm.
Bobwhite Quail	tech	No significant impairment at 2-20ppm dietary levels.
Mallard Duck	tech	Possible but not statistically significant effects on embryo viability at 15 ppm.
Bobwhite Quail	tech	No effects at up to 30ppm.

These studies indicate that the NOAEL is approximately 15 ppm, based on embryo viability in the mallard. The guideline requirements for avian reproduction studies have been fulfilled. (MRID 00097892, 00161574, 00191573)

iii. Mammals

Wild mammal testing is required on a case-by-case basis, depending on the results of lower tier laboratory mammalian studies, intended use pattern and pertinent environmental fate characteristics. In most cases, and for Terbufos in particular, rodent toxicity values obtained from the Agency's Health Effects Division (HED) substitute for wild mammal testing. Mammalian toxicity results are listed below.

Mammalian Acute Oral Toxicity Findings

Species	% AI	LD_{50} male; female (mg/kg)	Conclusions
Rat	96.7	4.5; 9.0	very highly toxic
Rat	86.0	1.74; 1.57	very highly toxic
Dog	96.7	4.5; 6.3	very highly toxic
Mouse	97.7	3.5; 9.2	very highly toxic

These tests show that Terbufos is very highly toxic to mammals.

iv. Simulated and/or Actual Field Tests

Simulated or actual field tests are required on a case-by-case basis to support the registration of an end-use product intended for outdoor application. These tests are required to support the registration of an end-use product if the use of the pesticide is likely to result in adverse effects on wildlife exposed to the pesticide, and if actual or simulated field tests can yield data useful in assessing such risk. Simulated and /or actual field testing with birds is required due to the high acute toxicity of Terbufos to birds and the potential for avian exposure to granules at or near the soil surface over the large acreage of agricultural land treated with Terbufos.

Results of field studies (71-5) with Terbufos are summarized below.

Terrestrial Field Study. Counter 15G applied to corn fields at 1 lb ai/A at time of plant showed minimal acute effects on wildlife; however carcass searches, residue analyses, and miscellaneous wildlife observations were limited. (MRID 00085178, 00085180, 00087726). The study partially fulfills the data requirement.

Simulated Field Study, exposure to treated soil. Ring-necked pheasants were exposed to soil treated with Counter 15G at a rate equivalent to 1 to 5 lbs ai/A and residues were not detected in soil 22 days after initial exposure. No poisoning symptoms were observed during 55 days of observation following treatment. Two of three birds exposed to a simulated spill died within 12 hours of initial exposure. The study is not required to fulfill the data requirement. (MRID 00085179,00085183, FEOTER01)

Terrestrial Field Study. Terbufos was applied at planting at 2.6 lbs ai/A and 10 weeks later as a broadcast aerial application at 1 lb ai/A to a cornfield in Maryland. Following the at planting application several species of wildlife were observed exhibiting signs of cholinergic poisoning. These included: one bluebird, one morning dove, one blue jay, one robin and one brown-headed cowbird. The bluejay contained residues of 0.24 ppm. Seven feather spots were also found. Following the aerial application eight dead birds, one affected bird, 14 mammals, one reptile, six feather spots and a fur spot were found. The study fulfills the data requirement. (MRID BAOTER01)

Terrestrial Field Study. Three seasons of field research were conducted from 1987 to 1989 in south central Iowa to assess the environmental behavior of Terbufos on wildlife in a corn agro-ecosystem. Monitoring and biochemical sampling techniques showed relatively low exposure to most species sampled. Results from starling nest box monitoring in the second year suggested some effects in reproduction parameters sampled and third year passerine blood plasma samples showed a significant difference between in-furrow treatment sites and controls in bluejay ChE levels. The study fulfills the data requirement. (MRID 409855-01, 414758-01)

Simulated Field Study. A study was conducted to compare the effects of Counter 15G to Counter 20CR on bobwhite quail and brown-headed cowbirds. Terbufos was applied at time of corn planting in pens using band and in-furrow applications. Despite study limitations, the results suggest that both

formulations could impact non-target wildlife species. All treatment pens showed higher mortality rates than controls. The study is not required. (MRID 415088-01, 41849201)

b. Toxicity to Aquatic Animals

i. Freshwater Fish

Fish Acute with Technical. In order to establish the toxicity of a pesticide to freshwater fish, the minimum data required on the technical grade of the active ingredient are two freshwater fish toxicity studies (72-1). One study should use a coldwater species (preferably the rainbow trout), and the other should use a warmwater species (preferably the bluegill sunfish).

Freshwater Fish Acute Toxicity Findings (Technical)

Species	% AI	LC_{50} (ppb)	Conclusions
Bluegill sunfish	86.0	0.77 (95% CI 0.72-0.83)	very highly toxic
Bluegill sunfish	86.3	3.8 (2.8-4.9)	very highly toxic
Bluegill sunfish	88.6	0.87 (0.77-1.0)	very highly toxic
Brown trout	86.0	20 (12.6-34.3)	very highly toxic
Rainbow trout	86.3	9.4 (7.7-11.4)	very highly toxic
Channel catfish	88.6	9.6 (8.5-11.1)	very highly toxic

The results of four of the 96-hour acute toxicity studies indicate that Terbufos is very highly toxic to both cold and warm water fish. The guideline requirement for acute toxicity testing of the technical on freshwater fish is fulfilled. (MRID #s 00087718, 00037483, 00085176)

Fish Acute with End Use Product. Two 96-hr LC_{50} fish studies using the 15% granular formulation may be needed for hazard evaluation of Terbufos if the LC_{50} of the technical grade of active ingredient approximates the expected residue level in the aquatic environment when the pesticide product is used as directed, or if a product component other than the active ingredient is expected to substantially enhance the toxicity of the active ingredient. If needed, one study should be conducted on a cold water species and one on a warm water species. Fish LC_{50} tests conducted with the 15 % granular formulation of Terbufos are listed below:

Freshwater Fish Acute Toxicity Findings (End Use/15 G formulation)

Species	% AI	LC_{50} (ppb) LC_{50} (ppb ai)	Toxicity category	Study classification
Bluegill sunfish	15	12.3 (95% CI 9.8-15.2) 1.8 (1.5-2.3)	very highly toxic	core

Rainbow trout	15	59.7 (48.1-74.3) 9.0 (7.2-11)	very highly toxic	core

These results show that the 15% granular formulation of Terbufos is very highly toxic to freshwater fish. Results are comparable to results with technical Terbufos, on a ppb ai basis. (MRID #s FEOTER04, FEOTER05)

Fish Early Life Stage Test with Technical. A fish early life-stage test (72-4) is required because the toxicity of Terbufos to fish is less than 1 mg/kg. Results of the fish early life-stage test on Terbufos are given below.

Freshwater Fish Early Life Stage (Technical)

Species	% AI	Conclusions
Rainbow trout	98.5	The NOAEL was 1.4 ppb, the highest concentration tested. The MATC could not be calculated.

There is insufficient information to completely characterize the chronic toxicity of Terbufos to freshwater fish in an early life stage test. The study failed to meet the guideline requirements that "at least one test level must adversely affect a life stage." Chronic effects are anticipated at concentrations of >1.4 ppb and lower than levels causing acute effects (rainbow trout acute 96 hr LC50 about 10 ppb). (MRID #40009301)

ii. Freshwater Invertebrates

Acute toxicity. The minimum testing required to assess the hazard of a pesticide is a 48-hour freshwater aquatic invertebrate toxicity test with the technical (72-2), preferably using first instar *Daphnia magna* or early instar amphipods, stoneflies, mayflies, or midges.

Freshwater Invertebrate Toxicity Findings

Species	% AI	LC_{50} (ppb)	Conclusions
Daphnia magna (crustacea)	88.6	0.31 (95% CI 0.27-0.36)	very highly toxic
Crayfish (crustacea)	88.6	8.0 (6.9-10.2)	very highly toxic
Gammarus pseudolimnaeus[(1)(2)] (crustacea)	88	0.2 (0.1-0.3)	very highly toxic
Chironomus plumosus (Diptera)[(1)]	88	1.4 (1-2)	very highly toxic

[(1)] from Mayer and Ellersieck, 1986. Static studies. [(2)] 96-hour measurement

There is sufficient information to characterize Terbufos as very highly toxic to aquatic invertebrates. The guideline requirement is fulfilled although tests with crayfish are considered supplemental. (MRID FEOTER03, 00085176)

Chronic toxicity. An aquatic invertebrate life cycle test (72-4) is required because the acute toxicity of Terbufos to aquatic organisms is below 1 mg ai/L; the estimated concentration in aquatic environments is greater than 0.01 of the LC_{50}; the hydrolytic half-life is greater than 4 days, and Terbufos has broad use on corn. An aquatic invertebrate reproductive test with the water flea (*Daphnia magna*) is required to establish the chronic toxicity to aquatic invertebrates. Results from an acceptable study are displayed below:

Freshwater Invertebrate Life Cycle Findings

Species	% AI	MATC	Conclusions
Daphnia magna	98.4	NOAEC 30 ppt; LOAEC 76 ppt MATC 48 ppt	very highly toxic

This test indicates that Terbufos causes chronic toxic effects to freshwater invertebrates at extremely low levels. (MRID 00162525)

iii. Estuarine and Marine Animals

Acute toxicity testing with estuarine and marine organisms (72-3) is required when an end-use product is intended for direct application to the marine/estuarine environment or is expected to reach this environment in significant concentrations. The corn and sorghum uses of Terbufos may result in exposure to the estuarine environment.

The requirements under this category include a 96-hour LC_{50} for an estuarine fish, a 96-hour LC_{50} for shrimp, and either a 48-hour embryo-larvae study or a 96-hour shell deposition study with oysters (72-3a, c, b).

Estuarine/Marine Acute Toxicity Findings

Species	% Test Material (TGAI)	LC_{50}/EC_{50}	Conclusions
Eastern oyster (shell growth)	89.2	EC_{50}=0.20mg ai/l	highly toxic
Mysid	98.4	LC_{50}=0.22ppb	very highly toxic
	98	0.40ppb	very highly toxic
Sheepshead minnow	98	3.2ppb	very highly toxic
	98.4	1.6ppb	very highly toxic

There is sufficient information to characterize Terbufos as very highly toxic to estuarine/marine organisms and highly toxic to the Eastern oyster. The guideline requirement is fulfilled. (MRID 42381501, 00162523, 41373603, 41373602, 00162524)

Chronic toxicity information is not available for marine and estuarine animals.

5. Ecological Exposure and Risk Characterization

a. Evaluation of LOC exceedances

This section describes the determination of concerns for ecological effects based on the quotient method. Description of field information (incidents, field studies) is found in a subsequent section.

$$\text{Risk quotient} = \frac{\text{Exposure}}{\text{Toxicity}}$$

Following the quotient method, a risk quotient (RQ) is calculated based on an estimate of exposure and an estimate of toxicity: A finding of a concern results when the value of a RQ exceeds a Level of Concern (LOC). The values of LOCs are displayed in the table below. The value of the LOC depends on the category of nontarget organisms and also on the following categories of concern: (1) *acute high risk* - potential for acute risk is high and regulatory action may be warranted in addition to restricted use classification; (2) *acute/restricted use* - the potential for acute risk is high but may be mitigated through restricted use classification; (3) *acute/endangered species* - the potential for acute risk to endangered species is high and regulatory action may be warranted, and (4) *chronic risk* - the potential for chronic risk is high and regulatory action may be warranted.
Currently, EFED does not perform assessments for chronic risk to plants, acute or chronic risks to nontarget insects, or chronic risk from granular/bait formulations to mammalian or avian species.

The toxicity measurements used in the denominators of risk quotients are derived from required ecological effects studies. Examples of toxicity measurements from relatively short-term laboratory studies, used to assess *acute* concerns are LC_{50} (for fish and birds), LD_{50} (for birds and mammals, EC_{50} (for aquatic plants and aquatic invertebrates), and EC_{25} (for terrestrial plants). Examples of toxicity measurements from relatively longer-term studies, used to assess *chronic* effects are LOAEC (for birds, fish, and aquatic invertebrates), NOAEC (for birds, fish and aquatic invertebrates), and MATC (for fish and aquatic invertebrates). The NOAEC is used to assess chronic concerns for birds and mammals. Other values may be used when justified. Generally, the MATC (defined as the geometric mean of the NOAEC and LOAEC) is the chronic toxicity measurement used for fish and aquatic invertebrates. However, the NOAEC is used if the measurement end point is survival or production of offspring.

Formulae for risk quotients are given below, along with corresponding LOCs and risk presumptions.

Risk Presumptions for Terrestrial Animals

Risk Presumption	RQ	LOC
Birds		
Acute High Risk	EEC[1]/LC50 or LD50/sqft[2] or LD50/day[3]	0.5
Acute Restricted Use	EEC/LC50 or LD50/sqft or LD50/day (or LD50 < 50 mg/kg)	0.2
Acute Endangered Species	EEC/LC50 or LD50/sqft or LD50/day	0.1
Chronic Risk	EEC/NOAEC	1
Wild Mammals		
Acute High Risk	EEC/LC50 or LD50/sqft or LD50/day	0.5
Acute Restricted Use	EEC/LC50 or LD50/sqft or LD50/day (or LD50 < 50 mg/kg)	0.2
Acute Endangered Species	EEC/LC50 or LD50/sqft or LD50/day	0.1
Chronic Risk	EEC/NOAEC	1

[1] abbreviation for Estimated Environmental Concentration (ppm) on avian/mammalian food items
[2] $\frac{\text{mg/ft}^2}{\text{LD50 * wt. of bird}}$ [3] $\frac{\text{mg of toxicant consumed/day}}{\text{LD50 * wt. of bird}}$

Risk Presumptions for Aquatic Animals

Risk Presumption	RQ	LOC
Acute High Risk	EEC[1]/LC50 or EC50	0.5
Acute Restricted Use	EEC/LC50 or EC50	0.1
Acute Endangered Species	EEC/LC50 or EC50	0.05
Chronic Risk	EEC/MATC or NOAEC	1

[1] EEC = concentration in water (ppm or ppb)

Risk Presumptions for Plants

Risk Presumption	RQ	LOC
Terrestrial and Semi-Aquatic Plants		
Acute High Risk	EEC[1]/EC25	1
Acute Endangered Species	EEC/EC05 or NOAEC	1
Aquatic Plants		
Acute High Risk	EEC[2]/EC50	1
Acute Endangered Species	EEC/EC05 or NOAEC	1

[1] EEC = lb ai/A
[2] EEC = concentration in water (ppm or ppb)

i. Terrestrial LOC assessments

Granular pesticide products such as Terbufos represent a unique potential risk to nontarget wildlife in that granules may be ingested directly by birds foraging for seed and grit at or below the soil surface on treated areas. Birds and mammals may also ingest granules adhered to the surface of invertebrate prey items such as earthworms and grubs, or through ingestion of water or food sources contaminated with pesticides. In addition, wildlife species may receive dermal exposure through contact with treated soil. Because of these somewhat unique routes of exposure, particularly the potential for direct ingestion of the formulated product, the Agency uses a different approach for estimating exposure for granular formulations than that used for foliar application. Granular exposure is estimated by the Agency based on the amount of toxicant exposed per square foot of treated area.

Soil incorporation of granules reduces the number of exposed granules. Several researchers have confirmed that both band and in-furrow applications of granular pesticides with incorporation, using conventional commercial equipment, greatly reduce the number of exposed granules, but do not eliminate potential exposure to non-targets. Varying numbers of exposed granules may therefore result from each type of use specified on Terbufos product labels. However, in an effort to quantify and simplify the percentage of product exposed after application, the Agency has used the following mean estimates:

Percentage of COUNTER granules remaining exposed after application and incorporation

Application Method	% Exposure
Banded (in front or behind press wheel; applied over emergent plants[1])	15
In-furrow; Drill; Knifed-in	1

1Because cultivators are positioned on either side of the row, granules directly in line with seedlings will not be incorporated; actual exposure is therefore likely to be greater than this value.

The Agency notes that these exposure values are estimated for *along* treated rows where some type of incorporation is concurrent with application. The number of granules that may be found in turn areas at row *ends* where application equipment is raised from the soil may be considerably higher than along rows. Although label directions specify deep disking at row ends, in actual use the applicator cannot practically do this immediately after granules are deposited. An attempt to account for the greater percentage of granules exposed at the row ends would result in risk quotients somewhat larger than the values reported here.

The amount of Terbufos applied to each square foot of treated area for a labeled method of application is determined using the following calculation:

$$\text{ai (mg)/ft}^2 = (\text{ oz product per 1000 ft of row} * 28{,}349\text{mg/oz} * \%\text{ ai}) / (1000\text{ ft} * \text{width of band or furrow (ft)})$$

$$\text{Exposed ai (mg)/ft}^2 = \text{ai (mg)/ft}^2 * \%\text{ unincorporated}$$

$$\text{Exposed granules / ft}^2 = \text{Exposed mg ai/ft}^2 / (\%\text{ai} * \text{granule weight})$$

Tables in Appendix C.1 give the estimated concentrations of Terbufos and number of granules on or near the soil surface. Also shown in these tables is the number of granules equivalent to an LD_{50} for bird and mammal species of varying sizes. While the body weights selected are somewhat arbitrary,

they were chosen to represent the range of weights of the majority of bird and mammal species that frequent agro-ecosystems where Terbufos is used.

The Agency uses the calculation of risk quotients that are based on the amount of toxicant per unit area for identifying granular pesticides which pose high risk. These pesticides then warrant closer examination to evaluate if modifications of use are required to reduce concerns. The risk quotient is based on the number of LD50's to an individual animal per ft^2 exposed on or near the soil surface to indicate the potential to impact nontarget terrestrial species. Using the previous exposure information on toxicant per unit area the following formula gives the risk quotient used by the Agency to indicate potential effects to non-target terrestrial organisms.

$$\frac{\text{Granules}}{ft^2} \;/\; \frac{\text{Granules}}{LD_{50}} = \frac{LD_{50}}{ft^2}$$

Mammals appear to be somewhat more sensitive to Terbufos than birds. Testing of the technical grade material resulted in LD_{50} values that ranged from 1.57 mg/kg to 4.5 mg/kg for the laboratory rat and dog, respectively. Dietary testing resulted in a 30 day LC_{50} value of 26 ppm for the rat. Mammals have the same potential sources of exposure to granules as birds, with the exception of grit. Granules may be ingested directly while foraging for seeds or insects at or below the soil surface on treated areas, or adhering to the surface of prey items. Further, exposure may occur from contaminated food items after the chemical has moved from the granule and some exposure may occur through dermal absorption from either contact with surface granules or contaminated soil. As with birds, the Agency uses a risk quotient based on the number of LD_{50} per ft^2 exposed on or near the soil surface to indicate the potential to impact nontarget mammals.

Risk quotients for birds and mammals are displayed on the pages following. Risk quotients greater than 0.5 LD_{50}/ft^2 (level of concern) are considered to indicate the potential for high risk to non-target terrestrial organisms. For all uses, the level of concern is exceeded for Terbufos, for both birds and mammals. Tables below show the avian risk quotients for the various uses and application methods of Terbufos. Banded application of Terbufos the RQs tend to be somewhat greater due to the less efficient soil incorporation. For The complete calculations are displayed in tables provided in Appendix C.1.

Avian Risk Quotients and LOC's for Terbufos 20 CR formulation

USE/APPLICATION METHOD	APPLICATION RATE/oz. per 1000 ft of row	RISK QUOTIENT LD_{50}/FT2	
		27 G BIRD	170 G BIRD
FIELD CORN, POPCORN & SWEET CORN			
BANDED AT PLANTING	1.2	21	3.3
IN-FURROW AT PLANTING	1.2	8.4	1.3
BANDED POST EMERGENCE INCORPORATED	1.8	32	5.0
BANDED, AT CULTIVATION	1.2	21	3.3
GRAIN SORGHUM			
KNIFED-IN AT BEDDING	1.2	8.6	1.4
KNIFED-IN AT PLANTING	0.62	11	1.7
SUGARBEETS			
BANDED AT PLANTING	1.2	21	3.3
KNIFED-IN AT PLANTING	1.2	8.6	1.4
MODIFIED IN-FURROW AT PLANTING	1.2	8.4	1.3
BANDED POST EMERGENCE	1.2	21	3.3

Avian Risk Quotients and LOC's for Terbufos 15G formulation

Application Method	Formulation/ Use Rate	Risk Quotient LD_{50}/ft2	
		27 g Bird	170 g Bird
Field corn, popcorn & sweet corn			
Banded at planting	1.2 oz/1000 ft row	21	3.3
In-furrow at planting	1.2 oz/1000 ft row	8.4	1.3
Grain sorghum			
Banded at planting	1.2 oz/1000 ft row	21	3.3
Sugarbeets			
Banded at planting	1.2 oz/1000 ft row	21	3.3
In-furrow at planting	1.2 oz/1000 ft row	8.4	1.3
Post emergence banded	1.2 oz/1000 ft row	21	3.3

Note: the calculations are documented in an Addendum. RQ values are assumed according to the following criteria:

High Risk > 0.5
Restricted use > 0.2
Endangered Species > 0.1

Mammal Acute Risk Quotients and LOC's for Terbufos 20 CR

APPLICATION METHOD	APPLICATION RATE oz/1000 ft of row	RISK QUOTIENT LD_{50}/FT^2	
		25 G Mammal	1 kg Mammal
FIELD CORN, POPCORN & SWEET CORN			
BANDED AT PLANTING	1.2	217	5.4
IN-FURROW AT PLANTING	1.2	87	2.2
BANDED POST EMERGENCE INCORPORATED	1.8	327	8.2
BANDED, AT CULTIVATION	1.2	217	5.4
GRAIN SORGHUM			
KNIFED-IN AT BEDDING	1.2	89	2.2
KNIFED-IN AT PLANTING	0.62	111	2.8
SUGARBEETS			
BANDED AT PLANTING	1.2	217	5.4
KNIFED-IN AT PLANTING	1.2	89	2.2
MODIFIED IN-FURROW AT PLANTING	1.2	87	2.2
BANDED POST EMERGENCE	1.2	217	5.4

Mammal Acute Risk Quotients and LOC's for 15 G

Application Method	Use Rate (oz/1000 ft of row)	Risk Quotient LD_{50}/ft2	
		25 g Mammal	1 KG Mammal
Field corn, popcorn & sweet corn			
Banded at planting	1.2	216	5.4
In-furrow at planting	1.2	87	2.2
Grain sorghum			
Banded at planting	1.2	216	5.4
Sugarbeets			
Banded at planting	1.2	216	5.4
In-furrow at planting	1.2	87	2.2
Post emergence banded	1.2	216	5.4

Note: the calculations are documented in an Addendum. RQ values are assumed according to the following criteria:

High Risk > 0.5
Restricted use > 0.2
Endangered Species > 0.1

Chronic Risk. Laboratory studies indicate that Terbufos may present chronic effects. Results of a mallard chronic study suggested possible, but not statistically significant effects on embryo viability at dietary levels of 15 ppm Terbufos (Beavers 1986a). Another study with bobwhite quail found no reproductive effects at dietary levels up to 30 ppm Terbufos (Beavers 1986b). From the above mallard chronic study, a NOAEL of 15 ppm may be derived. A three generation rat reproduction study with technical Terbufos reported a NOAEL of 0.25 ppm and a LOAEL of 1 ppm. The major effect observed was an increase in offspring deaths as compared to controls.

ii. Aquatic LOC assessments

Standard procedures for determination concerns for adverse effects are based on risk quotients (RQs), which compare estimated environmental concentrations (EECs) to laboratory toxicity measurements. Risk quotients are displayed on the following two pages for all categories of aquatic animals (fish/invertebrate, acute/chronic, freshwater/marine/estuarine).

To estimate exposure, weather and agricultural practices were simulated based on 36 years of meteorological data. To obtain an acute risk quotient, an LC50 is divided is divided by the "peak EEC, which is the estimated concentration exceeded my the maximum yearly concentration, for 10% of years. To calculate a chronic risk quotient, the EEC calculation involves averaging concentration over a time interval comparable to the length of the toxicity study. For example a a 4-day EEC is the concentration exceed by at least one 4-day average, in 10% of years. The calculation of EECs is described in greater detail in Section C.1.c ("Water Resources").

EECs and RQs have been calculated for Terbufos in two ways (see tables on the pages following): The first set of results is for parent Terbufos; the second set represents the combined concentration of parent Terbufos, Terbufos sulfoxide, and Terbufos sulfone ("total OP residue").

The RQs on the following pages can be summarized as follows. For T-band applications to all three crops (application rates 1.3 - 2 lb ai/A) the following ranges of RQs are obtained using total OP residue:

- for fish/acute, RQ 3-17;
- for fish/chronic, RQ 2-8;
- for invert/acute, RQ 14-60;
- for invert/chronic, RQ 113-403.

These acute RQs all exceed acute high risk levels of concern, i.e., RQ>0.5, and the chronic RQs all exceed the level of concern, i.e., RQ>1. We find that consideration of the total OP residue raises acute EECs and RQs by a factor of 2.5 - 3X and raises chronic EECs and RQs by a factor of 15 - 50X, relative to results for parent Terbufos. The greater factor increase for the chronic results is presumed to be due to the persistence of metabolites. For application procedures other than T-band, the estimated exposures are equal to zero. However, incident data involving fish

kills demonstrates ecological risk with in-furrow applications to corn. The Agency believes that significant runoff can be associated with in-furrow applications for all three crops. We are concerned that incorporation options in the most recent PRZM version may not adequately represent the availability of the chemical for runoff.

Risk quotients for aquatic animals based on estimated concentration of parent Terbufos

Crop (lb ai/A)	Application Procedure	Estimated Environmental Concentration (EEC, ppb)			Risk Quotients by Crop, rate etc.					
					freshwater				marine /estuarine	
					fish		invertebrate		fish	invert.
					acute	chronic	acute	chronic	acute	acute
					Toxic concentration (LC50 or NOAEC, ppb) [1]					
					0.77	1.43	0.31	0.03	1.6	0.22
					Exposure column for EEC					
		Peak	21 day	60 day	peak	60 day	peak	21 day	peak	peak
corn 1.3 lb/A	T-band, 85% in top 2 cm	2.2	0.3	0.1	2.9	0.071	7.1	10	1.4	10
	In-Furrow, 100% at 1.25 in	[Estimated exposure = zero [2]]								
grain sorghum 2 lb/A	T-band, 85% in top 2 cm	4.5	0.6	0.2	6	0	15	20	2.8	20
	In-Furrow, 100% at 1 in	[Estimated exposure = zero [2]]								
sugar beets 2 lb/A	T-band, 85% in top 2 cm	1.6	0.2	0.06	2.1	0.043	5.2	6.7	1.0	7.3
	Knifed-in, 100% at 2 in	[Estimated exposure = zero [2]]								

[1] Toxicity Measurements: FW fish acute = LC50 for bluegill sunfish; FW fish chronic = NOAEC from rainbow trout life cycle. The NOAEC was taken to be the highest concentration tested because no level tested resulted in an adverse affect. (Guidelines require the chemical to be tested at a level high enough to adversely affect some life stage.) FW invert. acute = LC50 for *Daphnia magna* (Crustacea); FW invert. chronic = LOAEC for *D. magna*. M/E fish acute = LC50 for sheepshead minnow. M/E invert. acute = LC50 for mysid (Crustacea). Chronic toxicity measurements are not available for M/E fish and invertebrates.

[2] See discussion of model limitations in the environmental fate assessment. Incorporation options in the current version of the PRZM model may not adequately represent the availability of the chemical for runoff.

Risk quotients for aquatic animals based on estimated combined concentration of parent Terbufos, Terbufos sulfone, and Terbufos sulfoxide

Crop	Rate etc.	Estimated Environmental Concentration (EEC, ppb)			Risk Quotients by Crop, rate etc.					
					freshwater				marine /estuarine	
					fish		invertebrate		fish	invert.
					acute	chronic	acute	chronic	acute	acute
					Toxic concentration (ppb) (LC50 or NOAEC) [1]					
					0.77	1.43	0.31	0.03	1.6	0.22
		Peak	21 day	60 day	Exposure column for EEC					
					peak	60 day	peak	21 day	peak	peak
corn 1.3 lb/A	T-band, 85% in top 2 cm	5.4	4.6	4.3	7.0	3.1	17	153	3	25
	In-Furrow, 100% at 1.25 in	[Estimated exposure = zero [2]]								
grain sorghum 2 lb/A	T-band, 85% in top 2 cm	13.3	12.1	11	17	8	43	403	8.3	60
	In-Furrow, 100% at 1 in	[Estimated exposure = zero [2]]								
sugar beets 2 lb/A	T-band, 85% in top 2 cm	4.3	3.4	3	5.6	2.1	14	113	2.7	20
	Knifed-in, 100% at 2 in	[Estimated exposure = zero [2]]								

[1]Toxicity measurements here are from studies with parent Terbufos and are documented further in the preceding table.

[2] See discussion of model limitations in the environmental fate assessment. Incorporation options in the current version of the PRZM model may not adequately represent the availability of the chemical for runoff.

iii. Endangered Species

The established LOC for terrestrial species for granular products is 0.1 and for aquatic species 0.05. If the risk quotient, LD_{50}/ft^2 for terrestrial species and EEC/LC_{50} for aquatic species is equal to or greater than the LOC, potential risk is assumed for endangered species. The level of concern for endangered species, both aquatic and terrestrial, on an acute and chronic basis is exceeded for all uses of Terbufos.

The Endangered Species Protection Program is expected to become final in the future. Limitations on Terbufos use will be required to protect endangered and threatened species, but these limitations have not been defined and may be formulation specific. EPA anticipates that a consultation with the Fish and Wildlife Service will be conducted in accordance with the species-based priority approach described in the Program. After completion of consultation, registrants will be informed if label modifications are required. Such modifications would most likely consist of the generic label statement referring pesticide users to use limitations contained in county Bulletins.

b. Incidents and Field Studies

i. Terrestrial Incidents and Field Studies

The weight of available evidence provided by incidents and field studies suggests that Terbufos, both the 20CR and 15G formulations, presents an acute as well as a chronic risk to non-target wildlife species.

Few studies have been completed that evaluate the effects of Terbufos on nontarget wildlife species under field conditions, and those that have been completed are somewhat limited in scope and sensitivity. Nevertheless, the available studies indicate acute hazard and show some indication of potential chronic problems. For the 15G formulation effects appears to be limited to relatively few species. Data are relatively scant for the 20CR formulation but there are no grounds for considering that formulation less hazardous than the 15G formulation. Granules of the 20 CR formulation are expected to be more durable than those of the 15G formulation, and a few granules can be lethal to wildlife.

The record of terrestrial incidents for Terbufos (including the misuse incidents) is displayed in tables on the pages following. The most notable terrestrial incident occurred in 1996 in King County Texas. About 20 migrating Swainson's hawks were killed by Terbufos 15G. The registrant commissioned a team of scientists to conduct an assessment of the incident. The unpublished report developed by that team has been reviewed by the Agency. The report (Bennett et al.) draws the following conclusions: The hawks were killed while gorging on grubs exposed in a newly plowed field. Stomach contents were found to contain soil as well as grubs. The exposure of the birds to Terbufos resulted from failure to cover the furrows after plowing. The furrows were not properly

covered because of equipment failure associated with plowing under unusually wet soil conditions. The conclusion of the report is that the incident occurred under an unusual set of conditions.

Simulated and/or actual field tests (71-5) on Terbufos are summarized below.

1. *Terrestrial Field Study*. Counter 15G applied to corn fields at 1 lb ai/A at time of plant showed minimal acute effects on wildlife; however carcass searches, residue analyses, and miscellaneous wildlife observations were limited. (MRID 00085178, 00085180, 00087726).

2. *Simulated Field Study of exposure to treated soil*. Ring-necked pheasants were exposed to soil treated with Counter 15G at a rate equivalent to 1 to 5 lbs ai/A and residues were not detected 22 days after initial exposure. No poisoning symptoms were observed during 55 days of observation following treatment. Two of three birds exposed to a simulated spill died within 12 hours of initial exposure. (MRID 00085179,00085183, FEOTER01)

3. *Terrestrial Field Study*. Terbufos was applied at planting at 2.6 lbs ai/A and 10 weeks later as a broadcast aerial application at 1 lb ai/A to cornfield in Maryland. Following the at planting application several species of wildlife were observed exhibiting signs of cholinergic poisoning. These included: one bluebird, one morning dove, one blue jay, one robin and one brown-headed cowbird. The bluejay contained residues of 0.24 ppm. Seven feather spots were also found. Following the aerial application eight dead birds, one affected bird, 14 mammals, one reptile, six feather spots and a fur spot were found. (MRID BAOTER01)

4. *Terrestrial Field Study*. Three seasons of field research were conducted from 1987 to 1989 in south central Iowa to assess the environmental behavior of Terbufos on wildlife in a corn agro-ecosystem. Monitoring and biochemical sampling techniques showed relatively low exposure to most species sampled. Results from starling nest box monitoring in the second year suggested some effects in reproduction parameters sampled and third year passerine blood plasma samples showed a significant difference between in-furrow treatment sites and controls in bluejay ChE levels. (MRID 409855-01, 414758-01)

5. *Simulated Field Study*. Study was conducted to compare the effects of Counter 15G to Counter 20CR on bobwhite quail and brown-headed cowbirds. Terbufos was applied at corn plant in pens using band and in-furrow applications. Despite study limitations, the results suggest that both formulations could impact non-target wildlife species. All treatment pens showed higher mortality rates than controls. (MRID 415088-01, 41849201)

6. *Terrestrial Field Study*. Knapton and Mineau (1995) studied effects of Terbufos (Counter 15G) and Fonofos (Dyfonate 20G) in corn fields in southwestern Ontario. Birds were color banded before application and then tracked. There were nine control fields, six fields treated with Fonofos, and 5 fields treated with Terbufos. 228 song sparrows (*Melospiza melodia*) were marked. Territorial individuals were observed to spend some time foraging on cornfields. The study authors concluded

that there was no evidence that either insecticide affected survivorship of song sparrows, and there were no dramatic impacts in other bird species (horned lark, savannah sparrow, vesper sparrow). Reproductive success of song sparrows was evaluated based on 91 nests. No adverse effects were detected despite observation of parents collecting food for their young from corn fields.

In order to place the results in perspective, it is important to note that fields studies ordinarily involve limited data collection and high variability, even with the additional precision from following marked individuals. In the Knapton and Mineau study, the largest number of marked birds were song sparrows (*M. melodia*). Of 96 song sparrows marked in control plots, 13 (or 13.5%) were lost to tracking; in treated plots 12 of 69 marked song sparrows (17.4%) were lost to tracking. If it is assumed that there may be some difference in the disappearance rates between treated and control groups, the ratio 17.4/13.5=1.28 (a 'risk ratio') can be used to estimate the magnitude of the difference. (However, a chi-square test performed by the study authors indicates that treated and control groups are not statistically different.) Using standard formulae for a confidence interval for a risk ratio (Kleinbaum et al., 1982, Ch. 15), the risk ratio is between 0.62 and 2.6 with 95% confidence. The results for species other than song sparrows would be consistent with an even wider range of risk ratios because of fewer data for those species.

Terbufos Terrestrial Incidents

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
corn	1997	DE	2	Canada geese	**Highly Probable** Incident occurred in Felton, DE (Kent County) on May 27, 1997 in a 7 acre stand of field corn. The geese were feeding in the newly planted corn which had been treated with Counter 15G. There were heavy rains prior to the incident. Analysis of the stomach contents revealed 75 ppm of Terbufos (I007372-001).
misuse	1996	CD	NR	eagles	**Probable/Misuse.** Carcasses baited with Terbufos for coyote control in Saskatoon area of Canada (I004605-1; references newspaper article in Star Phoenix)
corn	1996	TX	20	Swainsons hawks	**Highly Probable/Misapplication.** An incident in occurred on April 27, 1996 near Dumas, Texas (King County) in which about 20 migrating Swainson's hawks were killed by Terbufos (Counter 15G). The registrant commissioned a team of scientists to conduct an assessment of the incident. The unpublished report developed by that team has been reviewed by the Agency. The report draws the following conclusions: The hawks were killed while gorging on grubs (larvae of the Southern masked chafer) exposed in a newly plowed field. Stomach contents were found to contain soil, grubs, and Terbufos residues ranging from 6.5 to 16 ppm. The exposure of the birds to Terbufos resulted from failure to cover the furrows after plowing. The furrows were not properly covered because of equipment failure associated with plowing under unusually wet soil conditions. In much of the field, the corn seed and the Terbufos granules were deposited on to the soil surface instead of inside the furrow. The dead hawks were discovered 7 days after planting. The conclusion of the report is that the incident occurred under an unusual set of conditions. (I003498-001; I006435C).
corn?	1995	WI	2	red-tailed hawk	**Highly Probable** An adult female and a hatchling red-tailed hawk were found at the base of a tree in Madison, WI. Meat taken from the crops of the hawks contained 12 and 13 ppm Terbufos. The investigator speculated that the prey of the hawks had been a rodent from a nearby corn field (I002993-012; I002733-043, USF&WS case file 2300).

Terbufos Terrestrial Incidents

Crop	Year	State	Number Affected	Species Affected	Certainty Index, Use Pattern, Residue and CHE Analysis, (Reference)
misuse?	1994	CD	4	bald eagles	**Highly Probable/Possible Misuse** An incident occurred in Vancouver, British Columbia involving 4 eagles. Analysis of the contents of the crop and stomach confirmed the presence of Terbufos and its oxidative degradates at levels that could have caused the death of the eagles. Because the eagles were found many months after the normal application time for Terbufos and the significant amounts of parent Terbufos (relative to the amounts of oxidative degradates) misuse is suspected (I002486).
Misuse	1994	NC	2	red wolf	**Highly Probable/Misuse** Two dead red wolves were found near a farm in NC in the Fall of 1994. Analysis of the stomach contents revealed "large quantities" of Terbufos (38 ppm), rabbit flesh, and shotgun pellets. The presence of these 3 items in the gut strongly supported a case of intentional poisoning. The wolves had been introduced by the U.S. Fish and Wildlife Service against the wishes of the owners of the farm (I002484).
sugar beets?	1992	OR	5-10	Bald eagles	**Highly Probable/Possible Misuse** Five bald eagle carcasses were collected in March, 1992 near Toulee Lake in the Klamath Basin Game Preserve, north of Klamath Falls OR. Analysis of the gut contents revealed Terbufos residues. The gut contents was mainly waterfowl. The source of the Terbufos was not known. The report noted that sugar beets are grown in the Klamath Falls area and Terbufos is registered on sugar beets. Ingestion of Terbufos laced bovine meat as a poison bait was also speculated since the incident occurred prior to planting of sugar beets and the registrant does not have any records of sale in this area.. (I000089, I000089-001, B0000-300-39; Bennett and Williams, 1996)

ii. Aquatic Incidents

No aquatic field studies are available to the Agency for Terbufos, but numerous aquatic incidents have been associated with Terbufos. These incidents confirm that Terbufos parent and/or Terbufos metabolites do often reach aquatic environments in concentrations lethal to aquatic organisms.

The incidents record for Terbufos was reviewed most recently on March 11, 1999, by D. Brassard, acting incident coordinator for EFED (memo D. Farrar, D. Brassard, and J. Breithaupt to P. Noyes). A table of incidents is provided in Appendix C.2. The incidents provide useful information for risk characterization, as considered in greater detail C.5.c below (ecological risk characterization).

c. Ecological Risk Characterization.

i. Terrestrial Risk Characterization

Standard LOC criteria indicate concerns for acute effects on birds and mammals for Terbufos 15G and 20G applied at all rates evaluated (1.2 oz. per 1000 row feet and higher). This concern is supported by field studies. This section provides additional information for characterization of the scope and likelihood of adverse effects.

Weight of evidence from terrestrial field studies. The weight of available evidence provided by incidents and field studies suggests that Terbufos, both the 20CR and 15G formulations, presents an acute as well as a chronic risk to non-target wildlife species. While some earlier drafts of the EFED RED chapter stated that the field studies available consistently document an acute hazard, the study by Knapton and Mineau (1995) did not provide evidence of acute or reproductive field effects, based on comparison of five fields treated with Counter 15G to nine control fields. However, it is always important to take note of the inherent limitations of field studies (see discussion in Section C.5.b.) In particular, field studies generally involve limited replication and high variability, potential for confounding with uncontrolled variables affecting survival, and a narrow range of field conditions investigated. Because of these limitations, it can be concluded that significant die-offs did not occurr, but the study does not establish that Terbufos does not pose a significant risk to birds.

Exposure of birds to granules. Granular pesticides represent a unique risk to wildlife in that granules may be ingested directly by birds foraging for seed and grit at or below the soil surface. Birds and mammals may also ingest granules adhered to the surface of invertebrate prey items such as earthworms and grubs (implicated in an incident for Terbufos), or through ingestion of water or food sources contaminated with pesticides. In addition, wildlife may receive dermal exposure through contact with treated soil.

Soil incorporation of granules reduces the number of exposed granules. Both band and in-furrow applications of granular pesticides with incorporation, using conventional commercial equipment, greatly reduce the number of exposed granules, but do not eliminate potential exposure to non-

targets. For determination of LOC exceedances the Agency has assumed that 15% of granules are exposed and available to birds for banded applications, and 1% for in-furrow, drill, and knifed-in. However, varying numbers of exposed granules may result from each type of use specified on Terbufos product labels.

The Agency notes that these exposure values are estimated for *along* treated rows where some type of incorporation is concurrent with application. The number of granules that may be found in turn areas at row *ends* where application equipment is raised from the soil may be considerably higher than along rows. Although label directions specify deep disking at row ends, in actual use the applicator cannot practically do this immediately after granules are deposited. Estimates for the number of applied granules exposed in turn row areas are therefore determined without adjustments for incorporation.

Effect of granule characteristics on terrestrial exposure. Factors that need to be considered when evaluating the potential for effects to nontarget wildlife include characteristics of the granule including size, shape and surface texture, composition of the carrier material, color, the period that they remain intact after application, the concentration of the toxicant per granule, and the chemical properties of the pesticide (e.g. persistence, bioaccumulation).

For avian species the similarity of the granular to natural forage or grit has been suggested as an important characteristic which may influence ingestion of granules. The likelihood of ingesting a lethal dose is related to the number of granules which contain an LD_{50}, and the number available. It seems logical, since most species will consume at least a few grit particles in the size range of Terbufos granules, that the fewer the number of granules equal to a toxic dose, the greater the number of species at risk.

For Terbufos 20CR, 2 to 15 granules are estimated to be equivalent to an LD_{50} depending on weight of the bird, suggesting the potential to impact a variety of species. (See calculations above and in addendum for terrestrial risk quotients.) That is, small birds would be expected to consume relatively few large granules; however, only a few are required to equal a lethal dose. While larger birds require on the average a greater number of granules to equal a lethal dose, they have a higher likelihood to consume a larger number of the granules.

For the 15G formulation, 41 to 257 granules are estimated to be equivalent to an LD_{50} depending on weight of the bird. This suggests that larger avian species are at lower risk due both to the relatively large number of granules needed to equal an LC_{50} and the lower probability of larger birds consuming the smaller granules in comparison to the range of grit sizes utilized by avian species in and around corn fields.

For the most part these factors have not been investigated to define their influence for the two formulations. Results of pen trials (simulated field studies with birds confined in pens) suggest that both formulations have the potential to impact non-target wildlife species. However, the data

collected are insufficient to draw inferences about the relative hazard of the two formulations to non-target species under actual use conditions. (MRID #s 415088-01, 418492-01)

Exposure of mammals. Mammals have the same potential sources of exposure to granules as birds, with the exception of grit. Granules may be ingested directly while foraging for seeds or insects at or below the soil surface on treated areas. Mammals may also ingest granules adhered to the surface of invertebrate prey items. Further, exposure may occur from contaminated food items after the chemical has moved from the granule and some exposure may occur through dermal absorption from either contact with surface granules or contaminated soil.

Persistence of Terbufos in the terrestrial environment. Because Terbufos is incorporated the relevant degradation processes are those that occur in soil. In soil Terbufos will degrade primarily by *hydrolysis and microbial degradation*. Under conditions favorable to microbial growth the *soil metabolic half-lives* range from 6 to 27 days in aerobic soil and 67 days in anaerobic soil. The *hydrolytic half lives* range from 12 to 14 days under abiotic conditions and typical environmental pHs.

Although Terbufos is unstable in irradiated water, *photolysis* is not expected to be a significant route of degradation, assuming incorporation. *Volatilization* may be a major dissipation route for the portion of parent Terbufos that remains on the surface of soil after incorporation.

The predominant *metabolites*, Terbufos sulfoxide and Terbufos sulfone, are more mobile and persistent than parent Terbufos, and may be equally toxic. The sulfoxide and sulfone have half-lives in aerobic soil of 116 and 96 days, respectively.

Additional details are given in the Environmental Fate Assessment.

ii. Aquatic Risk Characterization

Concerns for adverse effects of parent Terbufos and/or Terbufos metabolites are strongly supported by widespread fish kill incidents. These concerns are further supported by standard LOC criteria which indicate concerns for adverse effects on aquatic (fresh water, estuarine/marine) fish and invertebrates for Terbufos 15G and 20G. The application of these criteria for Terbufos are based on toxicity information for parent Terbufos only, whereas actual impacts may be due to a large degree to Terbufos metabolites (Terbufos sulfone and sulfoxide) that are longer-lived than parent Terbufos. The Agency does not have ecological toxicity measurements for Terbufos metabolites, but experience with other organophosphorus pesticides suggests that sulfone and sulfoxide metabolites tend to have toxicity comparable to the parent compound (see EFEDs one-liner toxicity database).

This section provides additional information for characterization of the scope and likelihood of adverse effects.

Transport to surface water, persistence in surface water. Terbufos and Terbufos metabolites may be transported to surface water in runoff. Also, based on concentrations of parent Terbufos observed in ground water, these compounds may be transported to surface water in biologically significant concentrations via ground water.

EFED expects that Terbufos sufloxide and Terbufos sulfone will reach higher concentrations than parent Terbufos in water. However, there are inadequate monitoring data for these metabolites.

Effects of application procedure on estimated surface water concentrations. Modeling results obtained using PRZM and EXAMS suggest that application procedures can have a dramatic effect on surface water concentrations. For all three labeled crops the model results suggest negligible exposure for application procedures other than T-band application. However, EFED is concerned that incorporation options in the most recent PRZM version may not adequately represent the availability of the chemical for runoff. The Agency has received reports of aquatic incidents for corn, for all application procedures including in-furrow application. EFED believes that in-furrow application can be associated with significant runoff for any of the three labelled crops. While EFED believes that application procedures can have a large influence on routes of dissipation in the field, no data are available to support the dramatic difference in environmental concentrations suggested by the Terbufos modeling results..

Accumulation. The reported BCFs for Terbufos (320X to 940X), based on bioaccumulation in bluegill sunfish, indicate that parent Terbufos has only moderate potential for bioaccumulation.

Measured environmental concentrations relative to aquatic toxicity. Monitoring information indicates that concentrations of parent Terbufos and Terbufos metabolites sometimes reach levels that would adversely affect aquatic animals in laboratory toxicity studies. Parent Terbufos has been found to be toxic to several species of aquatic animals at concentrations under 1 ppb. Specifically for acute effects on fish, three studies with bluegill sunfish gave 96 hour LC_{50} values 0.8-3.8 ppb (geometric mean 1.4 ppb). (Note that some toxic effect is expected to occur below the LC_{50}.) There are several reports of parent Terbufos at concentrations exceeding 1 ppb in surface and ground water. As noted in the water quality assessment a spring in Iowa was found to have parent Terbufos at 20 ppb. Attempts to evaluate the frequency of toxic levels based on concentrations from monitoring studies would be subject to several difficulties including (1) monitoring data rarely captures the peak concentrations that are most significant for acute toxic effects; and (2) concentrations of Terbufos metabolites are not usually measured.

The Tier II aquatic exposure scenario and alternative scenarios. The Agency estimates aquatic exposure assuming a closed body of water similar in dimensions to a farm pond. Farm pond scenarios are relevant per se for reasons that include (1) the need of pond owners/managers to know if Terbufos will be a hazard to the fish in their ponds; and (2) use of farm ponds by various wildlife

not deliberately stocked in the ponds including snakes, turtles, amphibians, waterfowl, wading birds, and raccoons.

As a surrogate for other kinds of bodies of water, the scenario may be appropriate, under-protective, or over-protective. Important determinants of whether or not the scenario is protective include the potential for dilution, which depends on factors including the size of the water body, whether the body of water is static (lentic) or flowing (lotic), and the rapidity of mixing. The scenario is probably suitable as a screen for effects on larger fish that would tend to inhabit open water. The scenario may be appropriate for prairie potholes.

For some kinds of aquatic systems the scenario may actually underestimate exposure. These include many kinds of water bodies that may be particularly significant as habitat for fish and amphibians, including a variety of shallow and/or ephemeral bodies of water around fields, such as marshes, ditches, and ephemeral streams and pools. For some of these, the exposure may be similar to the concentration in undiluted runoff.

Even for bodies of water that have higher dilution than a farm pond overall, the assumption of instantaneous mixing may result in underestimation of exposure for the relatively slower-mixing zone close to shoreline. The zone close to shoreline is typically the zone of highest biological activity and may be particularly significant as habitat for early life stages of fish and for small species of fish and amphibians.

Characterization of Terbufos aquatic incidents. During the period from 1989 to 1998, seventy-eight fish mortality incidents have been reported involving Terbufos. Incidents reported annually ranged from 1 in 1996 to18 in 1990. The average rate of incidents is 8 per year.

Based on the information available to the Agency for these incidents, we can draw the following generalizations:

- For each reported incidents there was some evidence to associate the incident with use on corn.
- Eighty percent of incidents occurred in 5 corn belt states (IA, IN, IL, NE, OH)
- Incidents involved mortality of from 30 fish to 90,000 fish.
- All application methods for corn (band, t-band, and in furrow) caused incidents.
- All formulations (15G and 20CR) caused incidents.
- Large grassy buffer strips (350-1000 feet) did not prevent incidents in some cases.
- Incidents generally occurred from 2 days to 3 weeks after application.

For many incidents, the primary source of information is 6(a)2 reports submitted by American Cyanamid. In reports submitted by Cyanamid, it is usually asserted that incidents follow periods of heavy rainfall and often a specific value is given (e.g., ">3 inches"). However, no documentation is given to support the estimate and in at least some cases where records are available from nearby stations, values given by Cyanamid have not been supported: For a cluster of three incidents in Indiana, associated with Terbufos use by a single applicator in 1998 (I007924-006, I007795-002, I007795-001), the available rainfall information is data reported by the state of Indiana, from the Indiana Climate Page. Whereas Cyanamid reports >2 inches for one of these incidents and >5 inches for the other two, the available information indicates that rainfall did not exceed about half an inch for any day of the week preceding either incident. The information available to the Agency is consistent with incidents being caused by normal springtime rainfall. Similarly, claims that incidents occur on highly erodible soils or soil with high runoff potential are not substantiated.

Summary of Terbufos Aquatic Incidents on Corn, by Year.

Year	possible incidents		probable incidents		total incidents	# of Mortalities		Comments
	no analysis	no residues	normal use	misuse		average	Total*	
1998		2	7		9	4500	36000	All 20 CR, 8 t-band, 1 in furrow, all in Indiana , rainfall averaged 5.8"
1997	5				5			
1996	1				1			
1995	4				4			
1994	7		2		9	743	1486	140 ppb Terbufos in NC canal, 3" rain
1993	14		1		15	30	--	
1992	3				3	--	--	
1991	3	1	6	1	11	16427	98564	1 possible incident showed both Terbufos and chlorpyrifos residues
1990	5		13		18	1978	29670	
1989			3		3	1004	3012	
1989-1998	**42**	**3**	**32**	**1**	**78**	**4114**	**168732**	
1976-1985	**5**	**2**			**7**	**510**	**1020**	
Total	**47**	**5**	**32**	**1**	**85**	**3600**	**169752**	

* total number of mortalities for year only from incidents reporting number mortalities.

Significance of incidents in static water bodies. For the most part, Terbufos incidents occurred in static (lentic) water bodies such as farm ponds. EFED believes such incidents are significant for reasons that include (1) the value of managed fish in the farm ponds; (2) the

value of natural populations that farm ponds support (e.g., with breeding habitat, food, or water); and (3) the value of farm pond incidents as indicators of impacts on other surface water, particularly other shallow water close to treated fields.

In addition to managed fish, farm ponds are significant habitat for naturally occurring vertebrates including frogs, salamanders, snakes, turtles, birds, and mammals. Many of these species migrate overland between farm ponds and other aquatic habitat so that farm ponds contribute to wildlife populations for natural water bodies. Many species of amphibians (frogs, toads, and salamanders) depend on farm ponds and other small or ephemeral waters as breeding grounds and nurseries for developing tadpoles.

Farm pond incidents serve as indicators for impacts to other aquatic areas such as small streams and creeks. Pesticide monitoring data has shown that pesticide residues in streams and creeks adjacent to agricultural areas can reach levels similar to those predicted for farm ponds. Residues of Terbufos and its sulfone and sulfoxide degradates are highly mobile and can readily move into streams and creeks. Therefore, if fish kills are occurring in farm ponds, it is reasonably certain that aquatic organisms are being killed in streams and creeks adjacent to treated fields. Fish kills in farm ponds are more likely to be noticed and reported than those occurring in natural water bodies.

Limitations of incident information. For Terbufos, incident information is important in confirming aquatic impacts. Incidents can provide useful information on the circumstances where impacts occur in the field and are therefore a valuable tool for risk characterization. However, reliance on the *frequency* of incidents may significantly underestimate the extent of the actual impacts. Adverse ecological effects cannot be assumed to be reliably detected and reported. Before an incident can be reported, it must be observed and attributed to the pesticide. Reproductive effects or other sublethal effects, effects on eggs or small age classes, or impacts on relatively small species (invertebrates, amphibians, or small fish species) are likely to escape immediate detection. The only invertebrate species cited in Terbufos related incidents are crayfish, which are relatively conspicuous invertebrates.

The attribution of incidents to a particular pesticide is subject to both "false positives" and "false negatives." An incident actually caused by Terbufos cannot be attributed to Terbufos unless there is information that the pesticide has been used recently in the vicinity of the incident. This is perhaps unlikely if the incident occurs days after application.

Comparison of incident report frequencies. The Ecological Incident Information System (EIIS) is a repository of 2,915 ecological incidents submitted by state and federal agencies, diagnostic laboratories, and pesticide registrants. Review of the fish mortality from EIIS leads EFED to conclude that the use of Terbufos ranks fourth in pesticide-induced fish kill incidents in the United States (see Table below), and the leading cause of pesticide-related fish kill incidents from the use on field corn. Tefluthrin, with 10 incidents, ranks second in fish kill incidents on corn.

Top Four Pesticides Associated with Fish Kill Incidents in the United States (numbers of incidents from EIIS)

Active Ingredient	**# of incidents**	**Uses associated with majority of incidents**
Azinphos-methyl	172	sugarcane and cotton
chlorpyrifos	159	termiticides
endosulfan	94	agricultural areas, lettuce, tobacco, tomato, potato
Terbufos	62*	corn

* number of Terbufos incidents in EIIS; an additional 23 incidents were located in IDS that have not yet been entered into EIIS but were included in our analysis.

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